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DEVELOPMENT OF METEOROLOGICAL INSTRUMENTS

COUNTRY: USSR

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DEVELOPMENT OF METEOROLOGICAL INSTRUMENTS

by

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The volume and quality of the information obtained from the network of meteorological stations and observatories to a considerable degree depends on the extent of the technical equipment of the network, the perfection of the methods of measurement and the degree of preparation of the workers of the network.

On the eve of the October Revolution in Russia, the network of meteorological stations was rather extensive for that time; however, as in other countries, it was mainly an observation network, since only a small amount of data was obtained by means of measurements. This was determined by the general level of the development of science and technology of that time. However, even then at the Main Physical Observatory comprehensive geophysical research was already being carried out: on meteorology, aerology, atmospheric electricity, actinometry, terrestrial magnetism and other areas of the physics of the earth and atmosphere. The extensive work carried out at the Observatory on creation of methods and instruments for meteorological observations at the stations, which was largely credited to its director, G. I. Vil'd, contributed to this. Vil'd developed standards for the basic fixed meteorological instruments of that time (thermometers, rain gage with wind shield, capillary hygrometer), and also the siphon barometer, weather vane for measuring wind velocity and direction, gravimetric and floating evaporators, louvered booths and standards of pressure (normal barometers). All of this insured harmonious and uniform observations in all active meteorological stations.

During the first years of Soviet rule work at the Observatory on instrumental meteorology was directed towards maintaining existing equipment and apparatus, and also toward creation of Soviet models of the instruments in place of imported ones which go out of order. At that time this was very important, since as a result of the enemy blockade and restrictions it was extremely difficult to import equipment [1, 40]. At the Observatory Soviet models of the instruments with the help of kites, actinometric devices, devices for studying atmospheric electricity, etc. were

developed. Since meteorological instrumentation did not exist then in our country as an independent field, meteorological apparatus was manufactured mainly by small workshops in Leningrad (among them the Observatory workshops) and in the Ukraine.

The birth of Soviet meteorological instrumentation is attributed to the 20's, when Soviet instruments began to be developed for the reduced network. At the outset the Main Geophysical Observatory played a significant role in the development of Soviet meteorological instrument engineering. Over a period of several years the Observatory was almost the sole institution where new meteorological apparatus was developed, and its workshops were even suppliers of certain types of standard meteorological instruments.

In 1930 the first meteorological instrument in the USSR was created on the basis of the Observatory workshops for the production of meteorological instruments. Scientists of the Observatory were closely associated with this production. Work on instrumental meteorology was carried out by scientific coworkers of various specialties in almost all departments and institutes of the Observatory.[1] Here many aerological instruments, meteorological instruments for measuring the so-called basic meteorological elements (temperature, wind, air humidity, wind velocity, etc.), instruments for measuring radiant energy, elements of atmospheric electricity, transparency of the atmosphere, physical characteristics of the soil, much apparatus for carrying out special scientific experiments were constructed.

In the 20's until the beginning of the 30's, apparatus was constructed for the investigation of the free atmosphere: sounding, aviation, and aerostatic meteorographs were developed, radiosondes were invented and constructed (P. A. Molchanov). These developments insured rapid and extensive development of aerological research. During that period all of the basic actinometric instruments were constructed (S. I. Savinov and N. N. Kalitin), which insured the feasibility of organizing a homogeneous network of actinometric stations. A series of works on anemometry was also completed (M. I. Gol'tsman, Ye. I. Tikhomirov).

In 1930-1941 work on instrumental meteorology was focused mainly in the department of experimental meteorology, on the basis of which a department of instruments with a construction bureau was then created. In the 30's works were completed at the Observatory which permitted expansion of the volume of observations at the sites. Molchanov's radiosondes were perfected and mastered, new types of radiosondes were developed (B. M. Lebedev, A. A. Yershov), instruments for studying the altitude of various cloud layers - ceiling-height indicators (N. F. Kotov), actinometric instruments were perfected (N. N. Kalitin and Yu. D. Yanishevskiy), instruments were developed

[1] Over the course of several years institutes created on the basis of the largest departments of the Observatory entered into the structure of the Main Geophysical Observatory.

for measuring the range of visibility (V. A. Faas, V. F. Piskun), apparatus was developed for storm direction finding (B. F. Loch).

Simultaneously much attention was focused on the preparation of methodological handbooks for the networks on the use of new instruments.

In that same period apparatus was developed at the Observatory for equipping various scientific expeditions and studying the free atmosphere (P. A. Molchanov, S. I. Bernov, M. I. Gol'tsman, V. D. Tret'yakov, B. P. Karol' and others).

At the time of the Great Patriotic War the development of meteorological instruments was carried out in various departments, including the operating subdividion of the Main Geophysical Observatory at Leningrad. This work was directed towards insuring the requirements of the front subdivision of the Main Administration of the Hydrometeorological Service at the Council of Ministers of the USSR. Field wind gauges (V. D. Tret'yakov), visibility indicators (V. V. Sharanov) etc. were developed.

After the war until 1956 the development of instruments was carried out in the methodological department of the Main Geophysical Observatory under the leadership of V. N. Kedrolivanskiy and in a series of other departments.

In 1956 a department of meteorological instruments was again created. The greatest development of meteorological apparatus, created on the basis of results of scientific research, was centered in that department. Simultaneous development of apparatus primarily for scientific research purposes was carried out in a series of other department of the Observatory as well.

In the post-war period a great number of modern instruments were designed which permitted outfitting of a network of stations and extension of the number of measuring elements. The complex devices developed and adopted for distance measuring of soil temperature (D. P. Bespalov), wind elements (M. S. Sternzat, N. G. Protopopov), a device for gradient measurements of temperature and air humidity at the surface layer and on the open sea on ships and buoys (N. V. Kucherov, V. N. Svarchevskiy), complex new actinometric apparatus (Yu. D. Yanishevskiy), complex apparatus for measuring elements of atmospheric electricity (I. M. Imyanitov, Ya. M. Shvarts, P. S. Lydsar and others), devices for measuring ozone content in the atmosphere (G. P. Kushchin), for measuring and registering the range of visibility (V. A. Gavrilov, V. I. Goryshin), for measuring precipitation (V. D. Tret' yakov, I. N. Nechayev, L. R. Struzer and others).

Apparatus developed at the Main Geophysical Observatory in that period insured the carrying out of a wide complex of measurements on scientific expeditions (N. V. Kucherov, P. A. Borontsov and others), and also

fulfillment of a program of research at the time of the International Geophysical Year and International Year of the Quiet Sun.

At the beginning of the 60's the Observatory made a great contribution to the development of a general plan of the automation and technical equipping of the hydrometeorological network (N. P. Rusin, M. P. Timofeyav, M. S. Sternzat, N. V. Smirnova, L. R. Struzer and others). In accordance with this plan automatic stations with a wide program of measurements as well as a radar system for obtaining information on the nature of cloud fields over large territories were developed at the Main Geophysical Observatory.

A characteristic of the work in instrument engineering at the Observatory is the fact that it is directed towards adoption of new types of measurements and methods of detailed study of the atmosphere, which facilitates a solution of a series of theoretical and practical problems. In many cases an instrument developed at the Observatory for conducting research, which at first glance has a particular character, subsequently becomes a supply instrument and is used for making measurements in many meteorological stations. The measurement of solar radiation, elements of atmospheric electricity, ozone, etc. are examples.

Scientific work completed at the Observatory has largely determined and is determining at the present time the direction of meteorological instrument engineering. Despite the presence of special branches of instrument engineering and the special Scientific Research Institute of Hygrometeorological Instrument Engineering, the role of the Main Geophysical Observatory in the development of new apparatus for the network and various branches of the economy is great.

Co-workers at the Observatory have completed much work on preparation of specialists in the field of meteorological instrument engineering, in particular many scientists have written manuals and monographs on meteorological instruments and measuring techniques.

A short account of the work in the field of instrument engineering completed at the Observatory during 50 years, would occupy too much space. Therefore we will limit ourselves only to enumeration of several of the most interesting and important developments completed during that period by scientists and engineers of the Main Geophysical Observatory.

Apparatus for aerological study. Work on a perfection of aerological apparatus after the revolution was begun at the Observatory somewhat earlier than other work and at first was directed toward perfection and construction of Soviet instruments for studying the atmosphere with the help of pilot balloons and kites.

V. V. Kuznetsov perfected his theodolite for pilot balloon observation, and also developed new kites, kite and sounding balloons meteorographs, which were used in Pavlovsk. Somewhat later, (1921) P. A. Molchanov developed a meteorograph for sounding balloons of a lightened type, in which a sounder with the string rotated during the ascent of the balloon by the vane, while the construction of the vanes insured normal operation of the meteorograph both during ascent and during descent. These meteorographs, released by the workshops of the Main Geophysical Observatory, made it possible to obtain data on the temperature and moisture of the air of the free atmosphere up to a significant height at a series of points in the country.

In 1922 Molchanov proposed a nomogram for development of pilot balloon observations, widely known under the name of "the Molchanov circle". He also developed a theodolite for pilot balloon observations with automatic recording of vertical and horizontal angles, under which the ascending pilot balloon is visible.

In 1922-1923 the first Soviet aircraft meteorograph was developed at the Main Geophysical Observatory. Since 1924 it has begun to be used during airplane sounding of the atmosphere.

Molchanov's wedge radiosonde remains the greatest development in the field of meteorological instruments in its significance to its time. This invention with the wide possibilities which it opened for study of the atmosphere, should be evaluated as a most important discovery. Molchanov worked on the invention of the wedge radiosonde from 1923, and in January 1930 a successful start-up of this radiosonde occurred at Pavlovsk. The wedge radiosonde of Molchanov was the first radiosonde in the world, and over a period of many years it was one of the best perfected radiosondes. Improved models of this radiosonde, released from the Sverdlov Meteorological Instrument factory, were used in the years of the Patriotic War upon receipt of data for inspection of aviation, artillery, and other types of troops. On the whole, it was used for more than 25 years and successfully competed with foreign and other Soviet models. In 1939-1941 at the Main Geophysical Observatory V. M. Lebedez and A. A. Yershov with the participation of workers of industry developed the new, so-called commutation radiosonde in two variations: for ascent in balloons and for dropping from an airplane during study of the atmosphere over sparcely populated regions. The war prevented their adoption. Subsequently development of radiosondes of the Main Geophysical Observatory was not carried out. It was completed at the Central Aerological Observatory, the Scientific Research Institute of Hydrometeorological Instruments and the Sverdlov Hydrometeorological Instrument factory. Meteorological apparatus for ascent in aircraft, aerostats and helicopters were also constructed at the Main Geophysical Observatory.

P. A. Molchanov has developed an aerostatic radiosonde. P. A. Vorontsov over a period of many years, carrying out research on the boundary layer of the atmosphere, developed a series of special meteorographs for aerostats and helicopters which made it possible to obtain data not only on temperature, moisture of the air and wind velocity at various altitudes, but also a series of characteristics of the turbulence of the atmosphere. These developments are generalized in a monograph [3].

Apparatus for measurements at the surface layer of the atmosphere. Measurement of moisture, temperature of the air and soil temperature. Liquid thermometers in many cases do not satisfy the requirements of meteorologists. Therefore, over the course of many years other types of instruments have been developed.

V. V. Kuznetsov constructed an instrument for measuring the standard extreme values of temperature of the air in a boat [25]. He developed the thermohygrograph, which was successfully used over a period of several years in meteorological stations for recording the temperature and humidity of the air.

Research was carried out at the Observatory on the use of the thermocouple and thermal resistance for measuring the temperature of air, soil and water. V. N. Tikhomirova developed a device for measuring temperature of the air in which a battery of thermocouples was used with aspiration in order to increase the heat exchange of the warm layers with the air [55].

The adoption of instruments with thermal resistances for measuring temperature with high accuracy under natural conditions, at meteorological stations, encountered a series of difficulties. Only in the last decade, N. V. Kucherov, D. P. Bespalov and S. I. Zachek succeeded in surmounting these difficulties and constructing a device with copper and platinum thermal resistances, which are used successfully for measuring the temperature of air and soil at various depths.

Psychrometers and the capillary hygrometer are not perfect instruments; therefore the search for new methods and apparatus for measuring air humidity has been considered one of the most important and paramount problems of instrumental meteorology. M. I. Gol'tsman began in 1924 to develop a dew point hygrometer. Subsequently he constructed a series of better perfected dew point hygrometers in which observation of the condensate on the cooled mirror was accomplished with the help of an ultramicroscope by the dark field method, and then with the help of photoelements [7, 8, 22]. In 1936 one of the designs for these hygrometers was proposed for measuring air humidity in the stratosphere.

Further work on the construction of the dew point hygrometers was renewed only in the post-war years. N. P. Sateyev developed the automatically acting photoelectric dew point hygrometer, in which the cooling of the mirror is carried out with the help of a battery of semiconducting thermocouples [23, 61, 62]. L. F. Shcherbakov constructed a diffusion hygrometer, which determines directly the partial pressure of water vapor in atmospheric air [64].

Unfortunately, until this time there still had not been created sufficiently suitable instruments of broad application for measuring change in the humidity and temperature of the air over the entire interval. Previously meteorologists had to measure humidity with a psychrometer and capillary hygrometer. Later circumstances made the work on completion of the hygrometer carried out at the observatory by I. B. Sreznevsk, D. A. Smirnov, V. D. Tret'yakov [22, 57] et al, especially valuable.

Measurement of precipitation. At first glance simple rain gauges and precipitation gauges should not introduce serious fallibility into measurements. However, up to now we have not been able to measure the quantity of precipitation which falls with sufficient accuracy. Great attention was paid at the Main Geophysical Observatory to the perfection of rain gauges [39]. Rain gauge wind shields were studied and perfected. In 1941 V. D. Tret'yakov constructed a new precipitation gauge with a planar shield. He substituted a rain gauge with Nifer shield in a network of stations. In 1965 I. N. Nechayev and L. R. Struzer developed and tested a rain gauge which insures measurement of precipitation with greater accuracy than the existing supply-line rain gauge.

Instruments were also constructed at the Main Geophysical Observatory for measuring transfer of snow - a snow drift meter, for recording the amount of dew - a dewgraph and a series of other instruments for observation and evaluation of hydrometeorologists. Earlier these observations were conducted visually.

Measurement of wind characteristics. A considerable number of instruments were constructed at the Main Geophysical Observatory for measuring wind parameters. In 1928 instruments were constructed for studying the maximal levels of the wind: a mechanical instrument and a hydrostatic one - the hurricane meter of M. I. Gol'tsman. These instruments made it immediately possible to obtain interesting and practically important data on the maximal velocities of wind in the Markhot pass, Novaya Zemlya, I. Ay-Petri and other stations. The Gol'tsman hurricane meter was used in a series of meteorological stations [6, 7, 8, 22]. At the same time a highly sensitive cup annamometer was also constructed. A series of interesting designs for stationary instruments for measuring wind were developed by Tret'yakov. He also constructed a portable instrument for wind surveying - the Tret'yakov wind meter, which was rather widely used until recent times [22, 54]. In 1940-1942 S. I. Zilitinkevich developed an instrument based on the original principle of distance measurement of wind velocity [11].

In 1960-1964 development of a complex of wind measuring instruments was completed at the Observatory, which made it possible to carry out more detailed measurements of wind characteristics required for practical purposes at the hydrometeorological network. Thus, the wind bearing graph, known as the audograph of the wind M-12, made it possible for the first time to carry out direct recording of wind velocity, automatically averaged over a ten minute interval. The wind bearing graph M-64 and wind bearing meter M-63, developed by M. S. Sternzat and N. G. Protopopov in collaboration with workers in industry and the Scientific Research Institute of Hydrometeorological Instruments make it possible to obtain average, maximal, and instantaneous guides of wind velocity and wind direction [44]. The wind bearing meter, M-63, and wind bearing graph, M-12, received wide distribution in meteorological network stations.

Measurement of range of visibility (transparency of the atmosphere). Instrumental methods for measuring the range of visibility began to be developed in the 30's. In the Soviet Union one of the first instruments was the haze meter, developed in 1934 at the Leningrad State University by V. V. Sharonov. V. A. Faas developed several variations of the measuring device for visibility range [60]. His haze meter DM-4 was based on the principle of photometry by the method of extinguishing the contrast between the observed object and the background by means of superimposing haze. Haze of a given intensity artificially created a neutral field having been mixed into the field of vision of the instrument. DM-4 made it possible to carry out measurements directly in terms of meteorological range of visibility (transparency). V. F. Pushkin, who constructed a whole series of original visibility gauges [42, 43] carried on research in contact with the instrumental group headed by Faas.

In 1940 M. S. Sternzat constructed a differential photoelectric instrument for measuring transparency in fogs and clouds with direct readings of the measured quantity. A system of limiting diaphragms, which eliminates the effect of light on the internal sources in its reading was used in this instrument for the first time [22].

In 1942-1943 V. V. Sharonov developed a diaphanoscope, which made it possible to organize measurements of transparency of the atmosphere under conditions when a network of meteorological stations with its system of visual observations was to a considerable degree disrupted [22, 63].

In 1943-1945 in the operations subdivision of the Main Geophysical Observatory in Leningrad N. G. Boldyrev and O. D. Bartenev developed and studied stellar and visual photometry and with their help examined beacon lights in the Baltic Sea, and also made an evaluation of the accuracy of photometry of contrasts of natural objects and background [2].

V. A. Garvilov continued the work of V. A. Faas. In 1946-1954 he constructed the DM-7 and the visibility meter of the Main Geophysical Observatory, favorably distinguished by the fact that photometry during

measurements of visibility with their help is carried out at constant and increasing brightness of the field of vision, and also with convenient and simple measurement [4, 22]. In 1959 Gavrilov developed a new gauge for the visibility range with a telescopic system and "mark" inside the device; measurement is carried out by means of extinguishing the mark on the background of the observed object [4].

In 1952 V. I. Goryshin constructed a photoelectric recorder of transparency, which is used at the Air Weather Station of the Civil Air Fleet [22]. In 1963 he also developed a compensation photoelectric photometer, which makes it possible to carry out measurement (and recording) of meteorological visibility range with increased accuracy [10].

Measurements of elements of atmospheric electricity. The beginning of the resumption of atmospheric-electric measurements after the civil war was due to P. N. Tverskiy. The electrographs produced were used for organization of measurement of the gradient of the electric field and the conductivity of the atmosphere at the Main Geophysical Observatory and in a series of other stations.

Subsequently the development of new methods and instruments was begun. In 1923 V. N. Obolenskiy developed a device for measuring space charges in the atmosphere - a cotton filter, based on the principle of absorption of charged particles from the air, which are drawn through the filter. The cotton filter, in contrast to previously existing devices, possessed a high interference-resistance of measurement. In 1925 I. N. Kurchatov created a device for measuring the radioactivity of precipitation [13].

The years from 1936-1939 were especially fruitful. A. V. Pershin created an ionization chamber for measuring the radioactivity of precipitation and a differential ionization chamber in order to measure the radioactivity of the air [13]. M. N. Gerasimova developed a meter for light and medium ions, which makes it possible to take into account the conductivity and precipitation of ions on the screen during measurements of error as a result of current [13]. M. D. Kitsin created an instrument for measuring the dimensions and charges of drops of vapor, based on the principle of the change in trajectory of the fall of the drop under the influence of artificially created electric field [13]. R. A. Allik developed for the first time a device for prolonged recording of conductivity of air [13]. Under the leadership of P. N. Tverskiy observation of storm activity was organized in large territories (observation of atmospherics). In 1939 B. I. Loch created a device for direction finding of atmospherics from a narrow-sector the narrow-sector direction finder of atmospherics [33]. During subsequent years Loch worked on the perfection of this device. The narrow-sector direction finder of atmospherics was used for operative works over the course of the entire period of the Great Patriotic War.

In the post-war period development was begun principally of new types of instruments suitable for measuring elements of atmospheric electricity not only at the earth's surface (which had already been proved to be inadequate) but also in the free atmosphere. In 1947-1949 I. M. Imyanitov created a series of instruments [13], in particular an electrostatic fluxmeter for measuring an electric field, which has a very high sensitivity, slight lag and which is suitable for prolonged use in the open air. On the basis of the fluxmeter he created dynamic electrometers, suitable for making measurements of space charges and conductivity of the atmosphere under any aerial conditions and the voltage of the field in free atmosphere, in particular in storm clouds and during the falling of precipitation. Subsequently, I. M. Imyanitov and Ya. M. Shvarts developed variations of these instruments for installation on rockets and artificial earth satellites with the purpose of studying the electric fields in the upper atmosphere [15].

In 1956 V. A. Solov'yev and L. G. Makhotkin perfected an instrument for measuring the charge on a drop of vapor [50, 51].

In 1951-1953 Loch developed a storm recording device, which made it possible to set up in a network of stations registration of the number of storm discharges, which were previously evaluated qualitatively by visual observation [33]. In 1964 P. S. Lydzar perfected the storm recording device and constructed it on semi-conducting elements [34].

In 1957-1965 S. I. Zachek and I. M. Imyanitov created apparatus for measuring the conductivity of air at the earth's surface and in the free atmosphere [12, 14]. In the instrument for free atmosphere, the measuring electrodes were protected from particles falling on them from the clouds, which made it possible with the help of this instrument to carry out measurements of the conductivity of the atmosphere directly in the clouds as well.

Apparatus for actinometric measurements. Towards 1917 actinometric measurements at the Observatory were shut up rather extensively. However, they were carried out mainly with the help of imported instruments. Native apparatus was inadequate (practically only the actinometer of Mikhel'son).

During the years of Soviet rule apparatus was developed at the Observatory which made it possible by the 30's to create a homogeneous network of actinometric stations with a general program. At the present time actinometric measurements are carried out in many meteorological stations. They are executed with the help of apparatus developed at the Main Geophysical Observatory. This apparatus is also exported.

Mainly the development of Soviet actinometric apparatus are credited to the research of V. A. Mikhel'son, S. I. Savinov and N. N. Kalitin. By the 30's a large number of instruments had been created which were suitable

for wide use [16, 17, 18, 19, 37, 38, 45]. The bimetallic actinometer of V. A. Mikhel'son and models of it perfected by N. N. Kalitin and Yu. D. Protasov, were used for measuring direct solar radiation over a period of many years. The theory of the bimetallic actinometer developed by S. I. Savinov, made it possible to increase the reliability of the results of measurements obtained with the help of this instrument [46]. In 1923 V. A. Mikhel'son created a compensation balancing device (the absolute pyrgeometer). S. I. Savinov developed for the first time Soviet thermoelectric actinometers, pyranometers, pyrgeometers and a series of other instruments [45-47].

GRAPHICS
NOT REPRODUCIBLE

Sergey Ivanovich Savinov
(1865-1942)

In 1927-1929 Kalitin perfected the arago-Davy pyranometer, which subsequently made it possible with its help to carry out measurements of radiation falling on a horizontal surface [16]. More accurate results of measurement were obtained with a Kalitin evacuated thermoelectric pyranometer, since the indication of this instrument does not depend on wind. Kalitin also developed a new type of actinometer, like the albedometer, a photometer for measuring illumination and a series of other instruments [18-20]. During subsequent years Yu. D. Yanishevskiy perfected all existing thermoelectric actinometric instruments and developed a series of new ones: the actinometer, pyranometer, balance devices for measuring long-wave radiation and a series of other instruments which are widely used in meteorological stations. He also developed a method for installing the instruments at the stations [65]. A series of original actinometric instruments was created by I. G. Lyutershteyn; in particular, in 1932 he constructed a balancing device with mercury thermometers [35].

In 1950 D. L. Laykhtman and N. V. Kucherov proposed a new absolute method of measuring currents of radiation and other currents of heat. This method is distinguished by the fact that the intensity of the current is determined by the rate of change of the temperature of a plate on the surface of which the radiation falls, at the moment of equalization of the temperature of the plate and that of the surrounding air. As a result of this the effect of wind velocity on the results of the measurement is excluded. On the basis of this method, its author created the differential pyrgeometer and a series of other instruments [22, 26, 29].

In 1956 G. T. Gushchin developed a Soviet type of ozonometer. It is discharged in series, and with its help observations are carried out in our ozonometric network [9].

Special meteorological apparatus for scientific research and for national economy. Instruments and devices of this type are extremely varied in construction and purpose. Apparatus developed by scientific colleagues at the Main Geophysical Observatory, was used for carrying out scientific research in the laboratories and under natural conditions of the atmosphere, in expecitions and at all latitudes, and is also used in a series of branches of agriculture.

Thus, by 1932-1933 the Observatory had developed meteorological apparatus for equipping the stratosphere balloon "USSR-1". Moreover, the difficulties of measurement under conditions of great altitude were overcome. Molchanov developed special meteorographs, Gol'tsman developed a device for measuring humidity and taking samples of air, Tret'yakov developed thermometers and oil barometers. A complex meteorological problem was solved by B. P. Karol' in the calibration and testing of these experimental devices [7, 49, 56].

In 1936 Karol' developed and carried out calibration and testing of meteorological apparatus for equipping the first polar drift station SP-1.

Instruments for measuring and recording the temperature and humidity of the air, atmospheric pressure and wind velocity were made sufficiently small and light in consideration of conditions of transporting and exploration the Arctic.

S. .uently many expeditions of the Observatory, and also complex expeditions at drift stations SP-4, SP-5, in Antarctica, on weather ships, in regions of irrigated land and in the deserts, which were carried out with participation of colleagues of the Observatory, equipped with extremely complex apparatus developed at the Main Geophysical Observatory.

For these purposes N. V. Kucherov developed a device for measuring and recording temperature gradients in the surface layer of the air and on buoys placed on an anchor in the open sea [27, 30], measuring tangential components and a series of characteristics of air turbulence, and also an absolute instrument for direct measurement of the heat current through the surface of the earth, determined by turbulence of the air [22, 2l]. In order to measure the wind profile V. N. Svarchevskaiy, Ye. N. Shadrin and B. I. Protopopov developed several types of contact annamometers. The original instruments for direct measurement of heat currents in the upper layers of the soil was developed by B. P. Bespalov. D. L. Laykhtman proposed an instrument for measuring the thermophysical characteristics of soil. It was executed in the form of a tubular probe with a heating filament and thermocouple (or by the thermometer of a resistor) inside and makes it possible to carry out measurements without disturbance of the natural structure of the soil. This instrument is also suitable for measuring characteristics of ice and other substances. A device for measuring temperature pulsations and wind direction was developed by M. S. Sternzat [52], for measuring the vertical component of air current velocity was developed by A. R. Konstantinov [31]. V. N. Svarchevskiy created a device for taking measurements in an airplane, at the surface layer and on weather ships with the use of semi-conducting transducers [48].

The original devices were developed by S. I. Zachek and V. E. Karpush for measuring air temperature and atmospheric pressure for the purpose of automatic introduction of corrections into refractions during astronomical observations. In order to measure pressure Karpush developed a principally new device, based in principle on weight compensation of forces developed by a bellows.

The radiation thermometer developed by V. L. Gayevskiy [5] has great scientific and practical importance. With its help measurements were carried out by the author of the temperature of the underlying surface of large territories. Its use in our craft for assurance of fishing fl...s of given water temperature in the region of the catch is extremely promisi...

N. V. Kucherov and M. S. Sternzat developed a frost signaling device, which automatically, according to data on the magnitudes of wind velocity,

radiation balance, and air temperature, warns in advance (after 1-3 hours) the probability of setting in of radiation frost [22].

The signal-control annamometer developed by Karpush and Sternzat has received wide distribution for anticipating and incorporation of protective means on objects during emerging of wind with velocities endangering the object.

The complex apparatus developed under the guidance of P. A. Vorontsov for measuring meteorological characteristics at the boundary layer of air (aerostatic and aircraft meteorographs, equilibrated balloons, etc.) occupy an important place.

In 1924 the beginning of creation of automatic stations occurred at the Main Geophysical Observatory. The invention of the radiosonde by Molchanov mentioned previously which also appeared essentially in automatic meteorological stations, was the next great step forward in this direction. In subsequent years work on automation was carried out at the Arctic and Antarctic Scientific Research Institutes and the Scientific Research Institute of Hydrometeorological Instruments, where automatic radiometeorological stations were developed (Automatic Radio Meteorological Station and Drifting Automatic Radiological Station), which were used for installations in poorly accessible regions of the country and on the ice of the Arctic. In 1959 on the recommendation of a scientist of the Council at the Observatory, scientific research work was begun on expansion of automation of meteorological measurements in the network of stations. The origin for this was, in particular, the fact that automation of only those stations which were intended for difficultly accessible regions may give a limited economic and technical effect and may not serve as a basis of technical equipping of the network [24, 53].

At the present time at the Main Geophysical Observatory several modifications of automatic stations have been developed. In particular, a modification of the UATGMS-1 insures measurement of temperature and humidity of the air, soil temperature in tenths of degrees, atmospheric pressure, average and maximal wind velocity, wind direction, visibility range and altitude of the lower limits of the clouds. Primary treatment of the results of these measurements is carried out automatically; data are coded and transmitted by telegraph lines of communication. The station carries out measurements over an established period or on call and gives out storm information. The accuracy of data given out by the station is close to the generally accepted norms. The possibility of manual introduction of data obtained by visual observation has also been forseen. At the Observatory and at other institutions other simpler variations of the stations have been developed which do not carry out treatment of the data. These stations are depended upon for sufficiently refined lines of communication and a centralized system of assembly, treatment and distribution of information.

Experimental models of both types of stations have been made by the Riga factory of hydrometeorological instruments. Results of comprehensive explorative testing make it possible to determine further paths and direction of work on automation of processes executed in the hydrometeorological network. However, at the present time it can already be confirmed that automatic stations of the UATGMS-1 type have application in airports, zonal observatories, where they can be most effectively used. They may also be used in other cases where the necessity arises for broad operative service of local economic organizations.

The development of special radar apparatus and methods of observation behind fields of clouds with the purpose of obtaining operational data on the nature of the clouds, presence of storms, showers and certain other hazards for aviation is a great achievement. At the Main Geophysical Observatory work on radar research of the atmosphere was begun in 1947. In 1958-1960 Ye. M. Sal'man carried out research for the purpose of selecting the most optimal characteristics and construction of a locator for meteorological works. The results of this research have been used particularly during creation of special meteorological radar MRL-1, which is the basic system for obtaining data on cloud fields, created in accordance with the general plan of automation and technical equipping of the Hydrometeorological Service. Sal'man developed a method for using this system. It is based on the application of a series of objective criteria during analysis of primary radar data in order to obtain an unequivocal evaluation of the nature of cloud fields and the state of the atmosphere in the region illuminated by the locator. The method developed permits improvement of assurance of aviation work by a fundamental method.

In conclusion one more extremely important aspect of the organization of work on experimental meteorology at the Main Geophysical Observatory should be noted, which includes the adoption of new instruments and the showing of the workers of the network in mastery of them.

The majority of instructions and manuals on meteorological instruments and measurements have been written by co-workers at the Main Geophysical Observatory. The Observatory is one of the centers of preparation and training of specialists for the network in new meteorological techniques. Over a period of many years much work on the preparation of specialists in the field of instrumental meteorology (inspectors, specialists in exploration of new apparatus) has been carried out by V. N. Kedrolivanskiy, B. P. Karol', Yu. D. Yanishevskiy, M. S. Sternzat, V. A. Gavrilov, N. G. Protopopov, N. P. Fateyev, V. I. Goryshin and others.

Colleagues at the Main Geophysical Observatory V. N. Kedrolivanskiy, M. S. Sternzat, I. M. Imyanitov, Yu. D. Yanishevskiy and others have published monographs on instrumental meteorology [8, 13, 21, 22, 36], in which almost all work on meteorological instruments is expressed and which are used in various scholarly institutions as textbooks during study of the corresponding courses.

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13. ABSTRACT

Advances in meteorology during 50 years of Soviet rule are reviewed. Instruments developed for aerological studies, for measurement of the surface layer of the atmosphere, and special meteorological instruments developed for scientific research and for the national economy are discussed. Contributions of prominent Soviet scientists are outlined.

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